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MAN'S VERTICAL ACCELERATION WHILE CROUCHING

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NOTICES

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FOREWORD

This study was initiated by the Crew Stations Branch, Human Engineering Division, Aerospace Medical Research Laboratories. This work fulfills a requirement under Project No. 7184, "Human Performance in Advanced Systems," Task No. 718405, "Design Criteria for Crew Stations in Advanced Systems." This research was conducted during February 1964. Acknowledgement is made to Mr. B. Dixon, Lear Siegler Service Inc., for his instrumentation and calibration of the force plate.

ABSTRACT

The vertical accelerations involved in crouching and returning to the erect position were computed from the measured forces applied by the subject's feet to a force plate. The subjects were simply instructed to squat, retrieve an object from the floor and return to the erect position in a normal manner. The average peak accelerations were found to range from 0.118 to 0.166 G. If an astronaut's acceleration pattern is the same under weightlessness, a restraint system or device capable of holding with a force equal to at least one third the astronaut's earth weight will be required to prevent his feet from leaving the floor when crouching and to prevent launching himself away from the floor when arising from a crouched position.

PUBLICATION REVIEW

This technical documentary report is approved.

Walter F. Grether

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MAN'S VERTICAL ACCELERATION WHILE CROUCHING

Donald D. Mueller, Captain, USAF

INTRODUCTION

A man whose work requires him to stand erect, frequently must stoop to view objects or crouch to touch objects that are too low to see or reach from the erect posture. The vertical acceleration of the man's center of mass during such movements would normally be of little interest or significance. In an orbiting spacecraft, however, where a condition of weightlessness exists, man must be tethered to his work station by means of spring-loaded tiedowns, adhesive footgear, or other means. Under these circumstances it becomes necessary to know approximately what range of vertical accelerations a man is likely to undergo while crouching so that adequate tiedown forces may be designed into the restraint or tether system.

Under normal gravity (1 G) conditions, a man crouches by relaxing his knee joints and allowing his legs to collapse at a controlled rate under the influence of his body weight. The maximum theoretical downward acceleration that can be attained during crouching occurs when the legs are drawn up so rapidly that the feet leave the floor and the body free-falls at an acceleration of 1 G or 9.81 meters per second per second. The upward acceleration, which slows his body's downward movement and initiates the upward motion in returning to the erect posture, is not limited in this fashion, but the experimental data shows that it is comparable in magnitude to the downward accelerations.

The minimum upward or downward accelerations are obviously zero. It would require a high degree of muscular exertion to achieve the maximum theoretical downward acceleration and, similarly, a slow "deep knee bend," which approaches the theoretical minimum downward acceleration, also requires considerable muscular effort. Hence, we may conclude that somewhere between these extremes there lies a range of crouching accelerations that are preferred because they minimize the muscular effort involved. The purpose of this study was to determine experimentally this range of preferred crouching accelerations. Although the mechanics of crouching under 1-G and zero-G conditions may in some cases be different, the preferred body accelerations probably will remain the same.

METHOD

A special force plate instrumented with strain gages was used to measure the vertical accelerations of each of 11 subjects as they stood on the plate and crouched to pick up objects from the floor (ref 1).* The vertical force on the plate was recorded by a direct read-out oscillograph. A typical oscillograph trace is shown in figure 1.

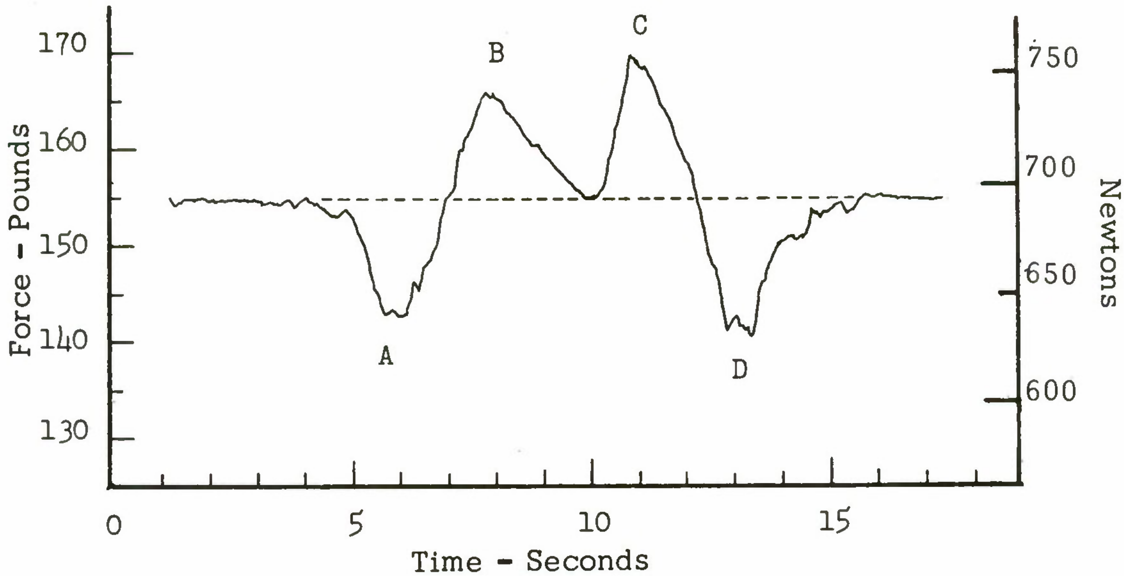

Figure 1. Typical Oscillograph Trace Showing Vertical Force on Instrumented Platform During Crouching

As the subject stood erect on the force plate the oscillograph recorded his normal body weight. The initial downward acceleration at the beginning of a crouching movement caused a momentary decrease in force indicated by A in figure 1. Similarly the deceleration as the subject came to rest in the fully crouched position caused a corresponding increase in force (B, figure 1). The subsequent return to the fully erect posture resulted in the increase and decrease in recorded force shown as C and D respectively in figure 1. The oscillograph trace recorded normal body force momentarily (between B and C) as the subject paused in the fully crouched position and again after returning to the fully erect posture.

The force fluctuations were converted to accelerations in units of G by dividing the change in force by the normal body weight. In all cases only peak accelerations were measured from the oscillograph records.

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*Roberts, J.F., Walking Responses Under Lunar and Low Gravity Conditions, AMRL-Technical Documentary Report-63-112, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, December 1961.

The 11 subjects were unaware of the purpose of the experiment. and each was asked to pick up ten coins, one at a time, returning to the upright posture after each retrieval. No instructions concerning speed were given so that each would crouch according to his own preference. Since four accelerations could be measured every time a subject crouched, a total of 440 accelerations were obtained in the test. The stature and weight of the 11 subjects are listed in table 1.

RESULTS AND CONCLUSIONS

The results of the experiment are presented graphically in figures 2-7 as histograms, showing the frequency distribution of accelerations. Each vertical bar represents a range of accelerations (0.02 G). The midpoint of each interval is labeled and the height of each bar is proportional to the number of times an acceleration was recorded which fell within the interval represented by that particular bar. The average acceleration appropriate to each figure is given. Since accelerations A and D are both downward, they are presented together in figure 6. Similarly, the two upward accelerations, B and C, are considered together in figure 7.

The oscillograph trace shown in figure 1 is fairly representative of all the data and illustrates some features reflected in figures 2-7. In almost every case accelerations A and D were approximately equal. Acceleration B, however, was generally lower and acceleration C generally higher than either A or D. What, if any, significance this fact has is open to conjecture.

The hypothesis that in the absence of instructions concerning speed subjects would select preferred crouching accelerations in a fairly narrow range was confirmed. The accelerations measured ranged from 0.04 G to 0.38 G. Because of the relatively small sample (N=11), no attempt was made to apply statistical methods, and a standard deviation from the mean was not computed. Nevertheless, the central tendency of the data is readily apparent from the histograms.

If a man would attain the same crouching accelerations under weightless conditions as he would under normal gravity conditions, then the data presented in figure 6 is important to the designer of a zero-G restraint or tether system. Since only downward accelerations of the man would tend to pull his feet from the floor, the data presented in figure 7 is not of immediate interest. Figure 6 shows that a restraint system would have to apply or sustain a force equal to one-third of the man's weight in order to accommodate the normal range of crouching accelerations without his feet leaving the floor in 99% of the cases.

For a 180-pound man the required force would be 60 pounds (267.0 newtons). Since a 60-pound (267.0 newton) force pulling a man to the floor through some type of harness may not be desirable from the standpoint of comfort, the data may indicate the desirability of attaching the feet directly to the floor by means of latches or Velcro® shoes.

TABLE 1

STATURE AND WEIGHT OF THE SUBJECTS

Subject Number	Stature (inches)	(meters)	Weight (pounds)	(newtons)
1	66.0	1.68	165	734
2	68.0	1.73	165	734
3	69.0	1.75	130	579
4	70.0	1.78	166	739
5	70.5	1.79	158	703
6	71.5	1.82	198	881
7	72.0	1.83	172	765
8	72.0	1.83	190	846
9	72.5	1.84	154	685
10	72.5	1.84	159	708
11	72.5	1.84	160	712

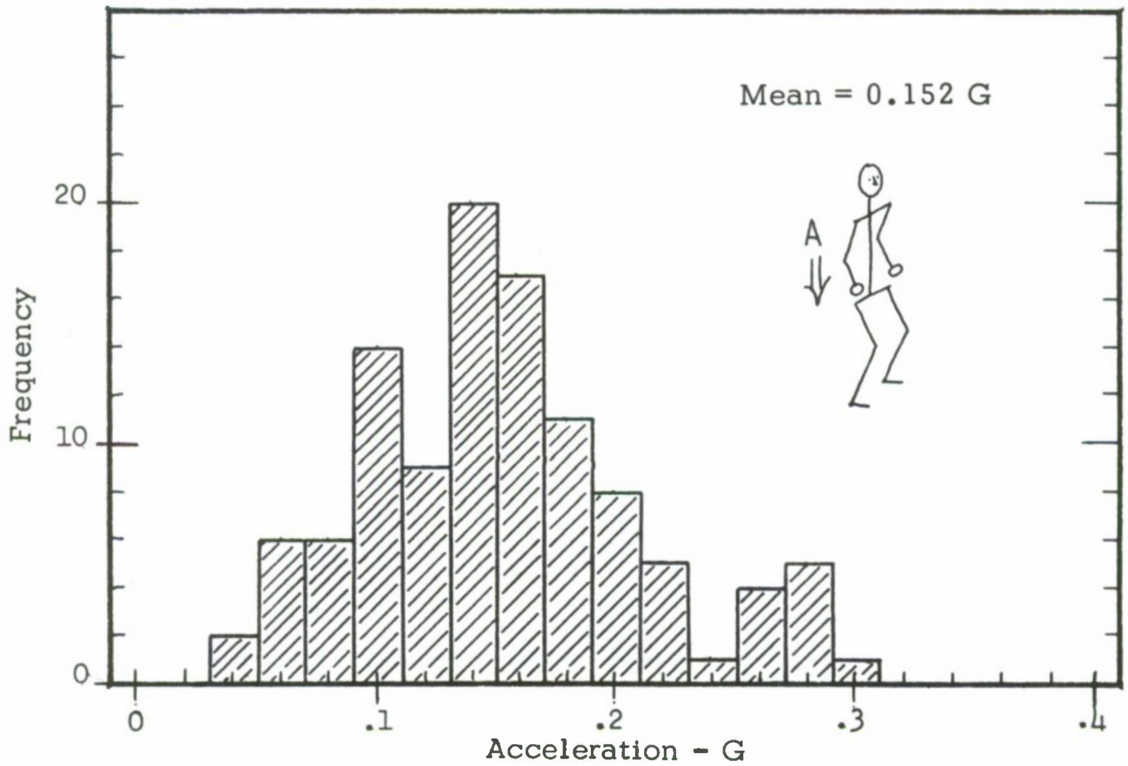

Figure 2. Initial Downward Acceleration, A

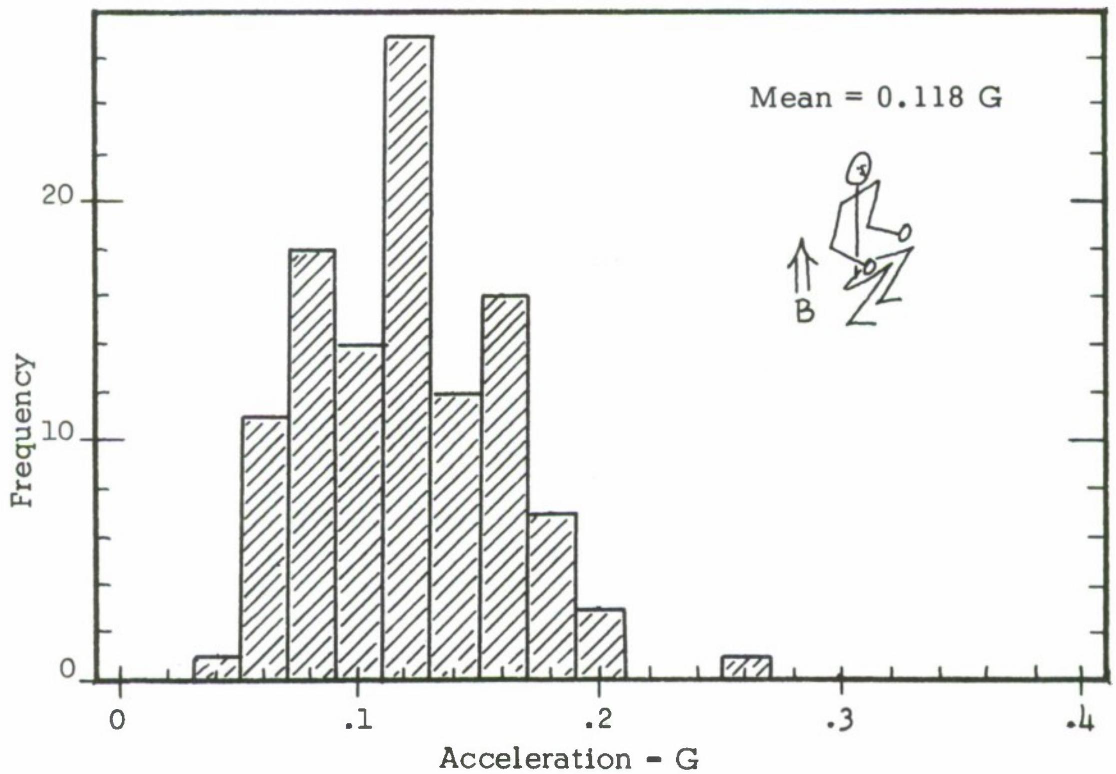

Figure 3. Deceleration in Crouched Position, B

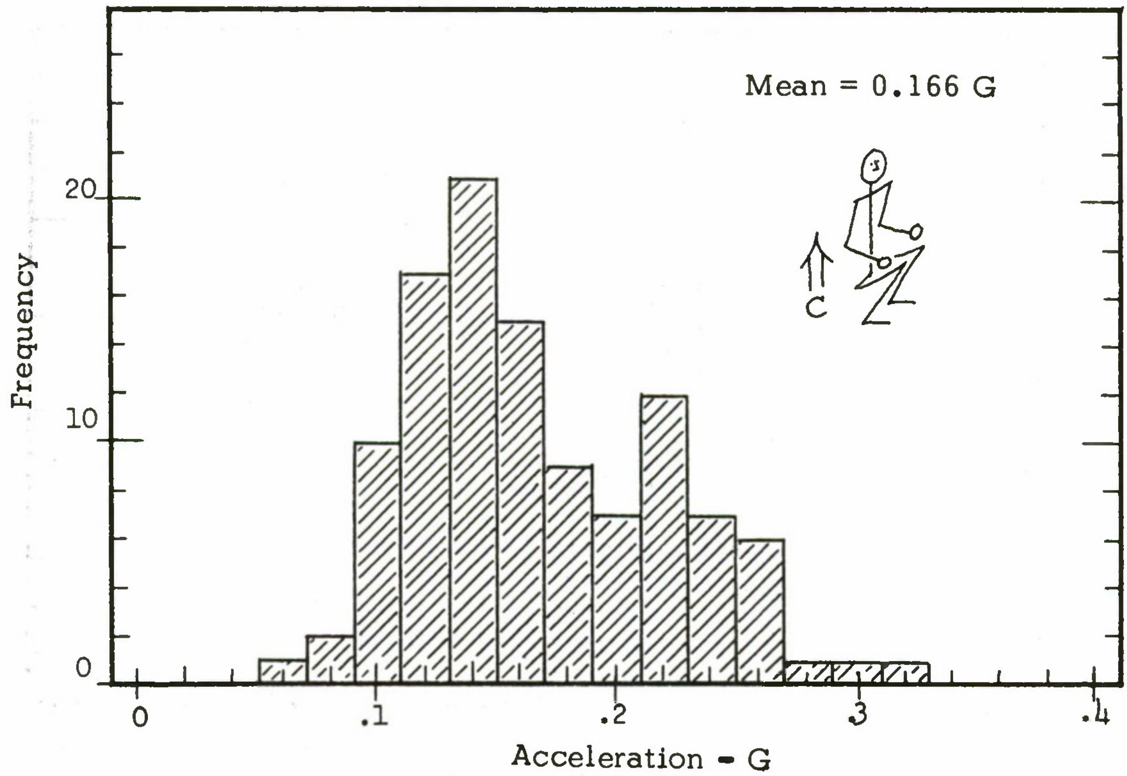

Figure 4. Initial Upward Acceleration, C

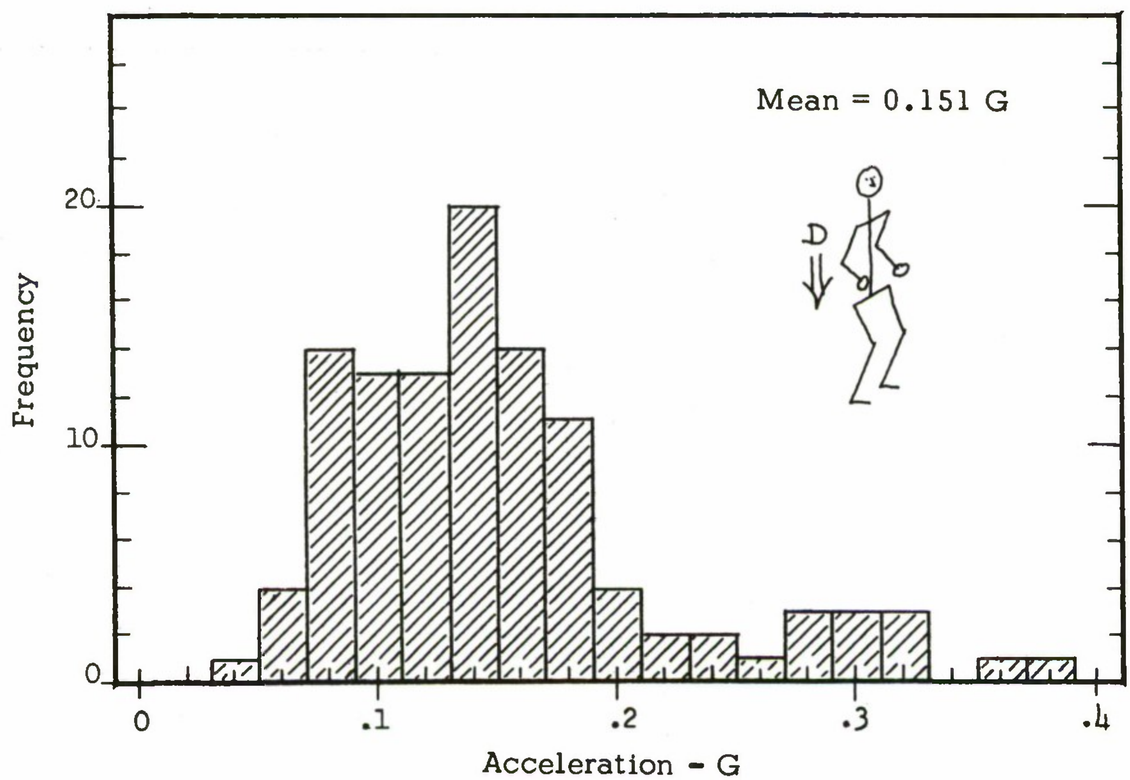

Figure 5. Deceleration in Erect Position, D

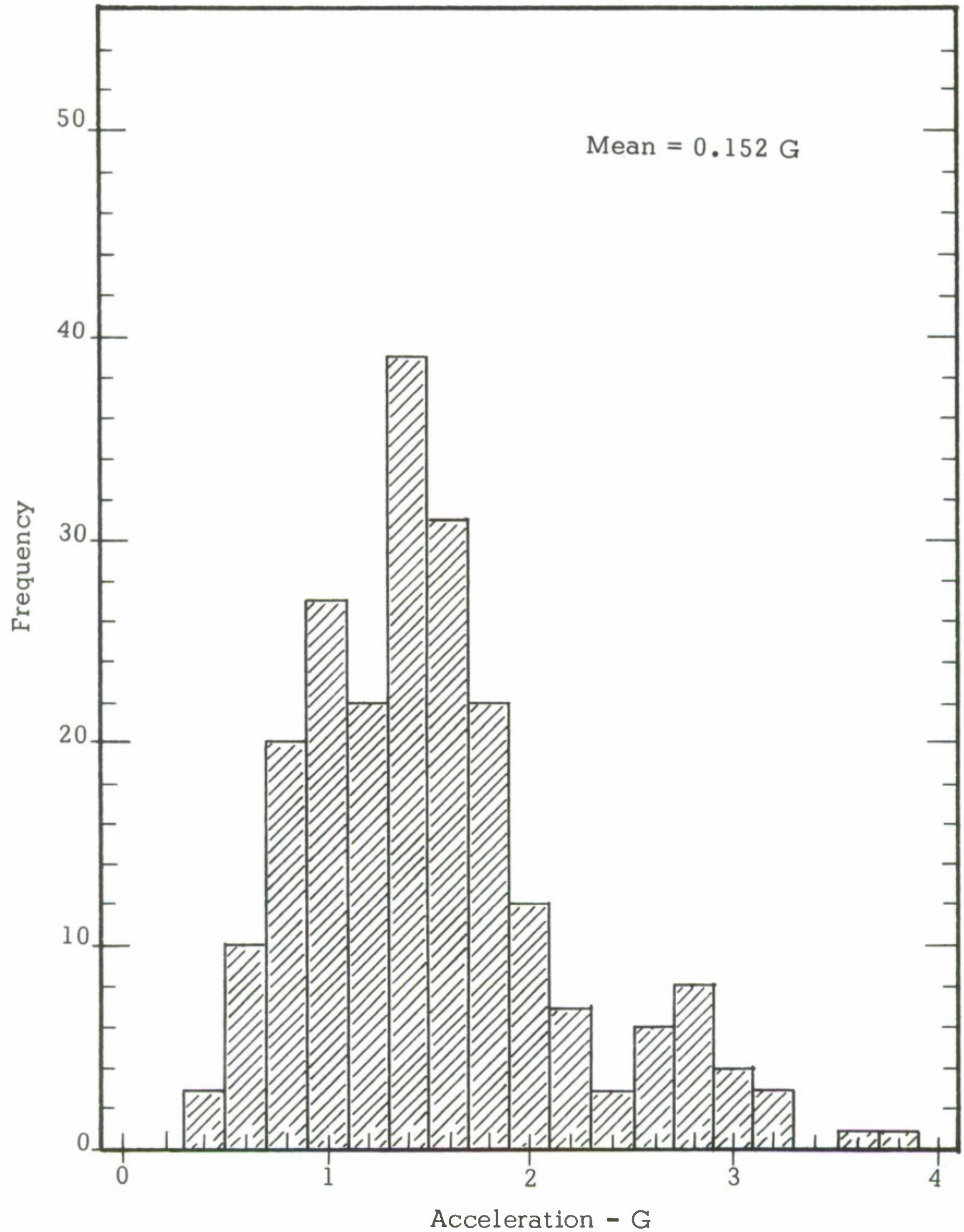

Figure 6. Composite of Downward Accelerations, A and D

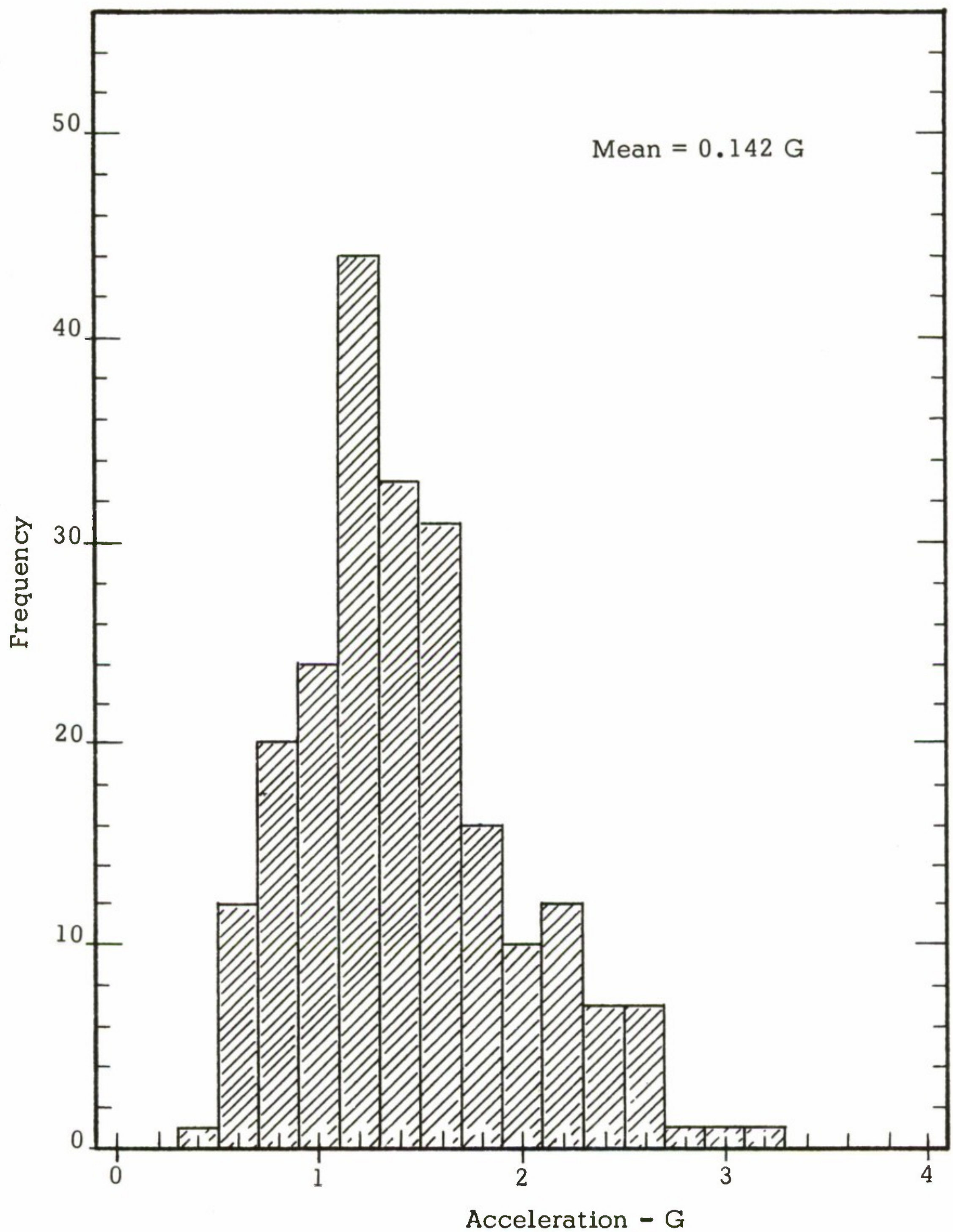

Figure 7. Composite of Upward Accelerations, B and C